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Assessment of silty sand liquefaction potential using hollow torsional tests—An energy approach

M.H. Baziar*, H. Sharafi

School of Civil Engineering, Iran University of Science and Technology, Tehran 16846-13114, Iran

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ABSTRACT

This research presents an investigation into the effect of fines content on the cyclic resistance ratio (CRR), dissipated energy up to liquefaction occurrence and excess pore water pressure generation of Firouzkooh silty sands from the shear stress and strain energy viewpoint. Sixty stress-controlled cyclic hollow torsional tests were conducted to directly measure excess pore water pressure generation at different levels of cyclic stress ratio (CSR). The specimens were tested under three different confining pressures ($\sigma'_3 = 60$, 120, and 240 kPa), and different fines content at a constant relative density ($D_r = 60\%$). The observed relations between dissipated strain energy per volume and different parameters such as pore water pressure are demonstrated. Based on the experimental evidence presented in this study, it can be concluded that the amount of cumulative dissipated energy, required for liquefaction occurrence, is independent of CSR for the specimens with constant relative density and confining pressure. On the other hand, effective confining pressure and fines content have strong effects on the accumulated strain energy.

1. Introduction

Liquefaction is one of the main damage caused by strong earthquakes. Although liquefaction of non-cohesive soils was observed many years ago, it has been a matter of great interest to geotechnical researchers for the last four decades, since the two destructive Niigata and Alaska earthquakes. Ever since, the study was mainly focused on clean sands or sands with a small portion of fines/gravel. However, recent earthquakes indicated that soils containing a significant percentage of silts may also liquefy due to shearing. Pioneer studies reported by Seed and his co-workers showed that sites containing silty sand behave differently from those containing relatively clean sand [1–4]. This observation was later confirmed by other studies [5–9].

The primary framework for the energy-based liquefaction assessment approach was represented by previous researchers [10]. The fact that the shear energy required to liquefy a soil deposit is independent of the stress history has become the main advantage of the energy approach. It was shown that there exists a unique relationship between the dissipated shear energy and the pore water pressure build up, which is independent of the shear stress history [11]. In addition, Liang et al. [12] applied random and sinusoidal excitations to the samples of Reid Bedford sand, and concluded that the strain energy required for liquefaction triggering is independent of the applied load pattern (harmonic or random). Therefore, it is not necessary to decompose the time history of shear stress to find an equivalent number of cycles for a chosen average stress or strain level. Using energy procedure to determine the liquefaction resistance includes the following specific advantages [13–16]:

1. Energy is associated with the quality of both shear stress and shear strain.
2. Energy is a scalar quantity which can be associated with the main earthquake parameters such as focal distance and magnitude of the earthquake.

The objective of this research is to study the effect of fines content (from 0% to 100%) on the cyclic resistance of silty sand using energy methods. To achieve this goal, the observed relation between the cumulative strain energy, dissipated within a unit volume of the sand–silt mixtures, and important parameters affecting liquefaction potential, such as fines content, and effective confining pressure were studied.

2. Review of previous researches

A few researchers have investigated the fines effect on the cyclic resistance (CRR) and the dissipated energy using stress-controlled hollow torsional test. Chang et al. [17] believed that

* Corresponding author. Tel./fax: +98 21 77240451.
E-mail addresses: baziar@iust.ac.ir (M.H. Baziar), h_sharafi@iust.ac.ir (H. Sharafi).

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